

(19)



Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number:

0 324 242
A2

(12)

EUROPEAN PATENT APPLICATION

(21) Application number: 88311739.2

(51) Int. Cl.4: C09J 7/02 , C09J 3/00

(22) Date of filing: 12.12.88

(30) Priority: 13.01.88 US 143461

(43) Date of publication of application:
19.07.89 Bulletin 89/29(54) Designated Contracting States:
DE FR GB

(71) Applicant: MINNESOTA MINING AND
MANUFACTURING COMPANY
3M Center, P.O. Box 33427
St. Paul, Minnesota 55133-3427(US)

(72) Inventor: Vesley, George Francis c/o
Minnesota Mining and
Manufacturing Company 2501 Hudson Road
P.O. Box 33427 St. Paul Minnesota 55133(US)
Inventor: Zimmerman, Patrick Gerard c/o
Minnesota Mining and
Manufacturing Company 2501 Hudson Road
P.O. Box 33427 St. Paul Minnesota 55133(US)

(74) Representative: Baillie, Iain Cameron et al
c/o Ladas & Parry Isartorplatz 5
D-8000 München 2(DE)

(54) Colored foamlike pressure-sensitive adhesive tape.

(57) The invention provides a foamlike pressure-sensitive adhesive tape comprising a flexible carrier supporting one or more pressure-sensitive adhesive layers, at least one layer of the pressure-sensitive adhesive having pigment-coated microbubbles dispersed therein having an average diameter from 5 to 200 micrometers, wherein the pigment coating comprises finely divided pigment particles, the average particle size being no greater than 1/100 the average size of the microbubbles.

The invention further relates to a method for making coated microbubbles involving rolling the pigment and the microbubbles in a cylindrical container with two or more mixing rods having lengths at least about equal to the interior diameter of the container, and a combined surface area at least about 5% of the interior surface area of the container.

EP 0 324 242 A2

COLORED FOAMLIKE PRESSURE-SENSITIVE ADHESIVE TAPE

Background of the InventionField of the Invention

5 The invention concerns pressure-sensitive adhesive tape which has a pressure-sensitive adhesive layer containing pigment-coated microbubbles. The adhesive preferably comprises a copolymer of (a) acrylic acid ester of nontertiary alcohol and (b) copolymerizable monomer having a polar group such as acrylic acid. Such an adhesive is disclosed in U.S. Patent Re. 24,906 (Ulrich).

Description of the Related Art

15 Foam-backed pressure-sensitive adhesive tape is commonly used to adhere an article to a substrate, e.g., sealing a skylight or attaching body-side moldings to automotive vehicles or simulated mullion bars to glass windows. The foam backings of such tapes often are pigmented with carbon black to afford a dark appearance that camouflages their presence. The pressure-sensitive adhesive tape of U.S. 4,223,067 (Levens), has a foamlike appearance and character, even though it is not a foam, and is useful for purposes previously requiring a foam-backed pressure-sensitive adhesive tape.

A foamlike tape of the Levens patent now on the market is made by ultraviolet polymerization of a layer of an adhesive-forming mixture containing colorless glass microbubbles which, due to multiple reflections of light at the surfaces of the microbubbles, act as a white pigment, thus making the tape undesirably conspicuous in uses such as those described above.

Because of its superior performance characteristics, the foamlike tape of the Levens patent is often preferred to foam-backed tapes for such purposes and would be more acceptable if its adhesive layer were colored to blend with the color of objects to which it will be adhered. If carbon black or other pigment were added to the photopolymerizable adhesive-forming mixture in amounts producing sufficient blackness to blend with dark objects, this would block the ultraviolet radiation from polymerizing the mixture to a pressure-sensitive state. Up to about 0.1 or 0.15 percent by weight of carbon black can be employed without undue interference with the polymerization of a 50-micrometer layer, but such small amounts produce only a gray color.

35 Although the microbubbles of the examples of the Levens patent are glass, they can also be polymeric of the type described in U.S. Patent No. 3,615,972 (Morehouse et al.) or U.S. Patent No. 4,287,308 (Nakayama et al.).

U.S. Patents No. 4,612,242 (Vesley et al.) and No. 4,618,525 (Chamberlain et al.) teach that by applying an inorganic, thin-film coating to the glass microbubbles, the tape of the aforementioned Levens patent can have a sufficiently dark appearance to be camouflaged. The Chamberlain patent also teaches that glass microbubbles having thin-film coatings can be used as fillers in other matrices to provide coherent articles other than tapes, thus affording good hiding power while also imparting aesthetically pleasing colors to normally transparent articles. However, the tapes of these references do have disadvantages in that the coated microbubbles involve complex processing equipment and conditions and are very expensive. Further, the variety of possible colors is limited as is the intensity of colors obtained from film-coated microbubbles alone. Somewhat deeper colors can be obtained by admixing additional pigment into the monomer matrix. However, this is generally accompanied by loss of adhesive properties due to reduced effectiveness of the photopolymerization of such a tape.

50 U.S. Patent No. 4,666,771 (Vesley et al.) teaches that by forming glass microbubbles of stained glass, the tape of the Levens patent can be colored and, when a pigment or dye is dispersed throughout the adhesive layer, the tape can be sufficiently darkened in appearance to be camouflaged. Stained glass microbubbles are highly pleasing aesthetically, however, processing of such bubbles is both difficult and expensive.

U.S. Patent No. 4,181,752, (Martens et al.) discloses a process for making pressure-sensitive adhesive tape which involves the photopolymerization of the alkyl esters of acrylic acid and the modifying monomers

to form the acrylate copolymers. It is also disclosed that the intensity and spectral distribution of the irradiation must be controlled in order to attain desirably high peel resistance and cohesive strength. The process disclosed is preferably carried out in the absence of oxygen and air which inhibit the polymerization reaction. Thus, it is normally carried out in an inert atmosphere such as nitrogen, carbon dioxide, helium, argon, etc. Air can also be excluded by sandwiching the liquid photopolymerizable mixture between layers of solid sheet material and irradiating through the sheet material.

Summary of the Invention

10

The foamlike pressure-sensitive adhesive tapes of the invention are equivalent in performance to the white foamlike tapes of the above-cited Levens patent. Tapes of the invention present a sufficiently dark or colored appearance to meet the needs mentioned above, and may be produced more easily and economically than dark tapes of the above cited references.

As compared to foamlike tapes of the above-cited Vesley and Chamberlain patents, tapes of the invention can have more intense color, e.g., more intense blackness without loss of adhesive or cohesive properties. Also, the foamlike tapes of the invention can have any desired color as opposed to tapes of the Vesley and Chamberlain patents being limited to such colors as can be provided by available thin-film coatings and by stained glasses capable of being formed into microbubbles.

The present invention provides foamlike pressure-sensitive adhesive tapes comprising a flexible carrier supporting one or more pressure-sensitive adhesive layers, at least one layer of the pressure-sensitive adhesive having pigment-coated microbubbles dispersed therein, the microbubbles having an average diameter from 5 to 200 micrometers, wherein the pigment coat comprises finely divided pigment particles, the average particle size being no greater than 1/100 the average size of the microbubbles.

The invention further provides a method for making pigment-coated microbubbles comprising the steps of:

(a) placing into a hollow cylindrical container
 (1) uncoated microbubbles
 (2) an effective amount of pigment, and
 (3) at least two mixing rods, each of the rods having a length at least about equal to the interior diameter of the container, the rods having a combined surface area at least about 5% of the interior surface area of the container, and

(b) rolling the container for a period of from about 3 minutes to about 15 minutes.

The invention further provides microbubbles made by the above process, and tapes made therewith.

As used herein, the word "pigment" includes particulate pigments, dyes, and coloring agents comprising other colorants as well as mixtures thereof.

40

Detailed Description of the Invention

The foamlike pressure-sensitive adhesive tape of the invention comprises pigment-coated microbubbles. To provide a uniform color, the average size of individual particles of the pigment should be 1/100 that of the average microbubble, preferably 1/1000. In preferred embodiments of the invention, the particles will have an average size of less than about 100 nanometers (nm), more preferably less than 20 nm. The average thickness for the pigment coating is believed to be in the range of from 50 nm to about 500 nm. The microbubbles may be glass or polymeric microbubbles, or a mixture thereof.

The novel foamlike pressure-sensitive adhesive tape, like that of the Levens patent, may be produced by photopolymerizing the microbubble-containing adhesive. However, the foamlike layer of the novel tape can have much more intense color, e.g., blackness, than could be achieved by photopolymerization using uncoated microbubbles in admixture with pigments. If carbon black or other pigment were added to the photopolymerizable adhesive-forming mixture in amounts producing sufficient blackness to blend with dark objects, this would block the ultraviolet radiation from polymerizing the mixture to a pressure-sensitive state. The percentage of carbon black that can be employed without undue interference with the polymerization produces only a gray color. Surprisingly, complete photopolymerization of the adhesive layer of the novel

tape within a reasonably short period of time is possible with pigment-coated microbubbles, yielding much darker colors.

When microbubbles are coated with carbon black or another pigment opaque to radiation between 300 and 400 nm, such pigment may comprise up to about 20% of the weight of the microbubbles. If substantially high r coating weights of such opaque pigments are employed, the pressure-sensitive adhesive might not become fully cured. Pigments which are partially transparent to such radiation may be used in larger amounts.

The pigment-coated microbubbles afford excellent hiding power to the novel foamlike tape, surprisingly so in view of the fact that their presence does not unduly inhibit photopolymerization. Even though a foamlike adhesive layer as thin as 0.1 mm has excellent hiding power, an otherwise identical layer having a thickness of 0.5 mm has been photopolymerized through its full thickness from a bank of lamps on only one side. By irradiating from both sides, it should be possible to produce foamlike adhesive layers as thick as 2.5 mm or more. When the pigment is carbon black and is present at from 0.5% to 10% by weight of the microbubbles, the foamlike adhesive layer has a black color which provides satisfactory camouflage for the adhesive in uses mentioned above.

Under microscopic examination of the pigment-coated microbubbles, the coats appear less intense. They may also appear somewhat grainy or splotchy even though an adhesive layer containing the pigment-coated microbubbles appears to the naked eye to have a uniform coloring.

The average diameter of the pigment-coated microbubbles should be from 5 to 200 micrometers, preferably between 20 to 80 micrometers. The pigment-coated microbubbles of the invention should have an average density not exceeding 1.0 g/cm³, preferably less than 0.4 g/cm³, and most preferably less than 0.2 g/cm³. Such density is determined using a Beckman pycnometer to determine the density, thus compensating for bulk distribution characteristics, as described in The American Society of Test Methods' Test No. ASTM D-2840-69.

The microbubbles may comprise up to 65 volume percent of the pressure-sensitive adhesive layer of the novel foamlike tape. It would be unduly difficult to make a coherent and uniform pressure-sensitive adhesive layer at more than 65 volume percent, whereas the advantages from using microbubbles may not be significantly realized at less than 5 volume percent. Preferably from 10 to 55 volume percent of the pressure-sensitive adhesive layer comprises microbubbles.

Useful glass microbubbles include those disclosed in U.S. Patent Nos. 3,365,315 (Beck et al.), 4,391,648, (Howell), 4,223,067 (Levens), and 4,666,771 (Vesley et al.), all of which are incorporated herein by reference. Pigment-coated glass microbubbles are commercially available from such suppliers as Rose Labs, Atlanta, Georgia.

Useful hollow polymeric microbubbles include those described in U.S. Patent Nos. 3,615,972, 4,075,238, and 4,287,308, incorporated herein by reference. The microbubbles are available from the Pierce & Stevens Company under the trade name "Microlite" in unexpanded form and "Miralite" in expanded form. Similar microbubbles are available from Kema Nord Plastics under the trade name "Expancel" and from Matsumoto Yushi Seiyaku under the trade name "Micropearl". In expanded form, the microbubbles have a specific density of approximately 0.02-0.036 g/cc. It is possible to include the unexpanded microbubbles in the pressure sensitive adhesive composition and subsequently heat them to cause expansion, but it is generally preferred to mix the expanded microbubbles into the adhesive. This process makes it easier to ensure that the hollow microbubbles in the final adhesive are substantially surrounded by at least a thin layer of adhesive.

Various methods exist for coating microbubbles; however, most techniques have significant disadvantages. Some techniques which would sufficiently distribute the pigment onto the surface of the microbubbles and result in adherence thereto, e.g., agitating the microbubbles with adequate amounts of pigment using milling spheres to distribute the pigment, have typically resulted in excessive damage to the microbubbles, including large amounts of breakage when glass microbubbles have been used. Methods causing lower amounts of damage, e.g., shaking or rolling microbubbles in the presence of pigment have typically resulted in inefficient distribution of the pigment onto the microbubbles or insufficient adherence of the pigment to the surface of the microbubbles. When tapes are made using such lightly coated microbubbles little if any improvement in color intensity is seen over tapes made with pigment merely admixed into the monomer matrix. Other techniques require considerable specialized processing and handling equipment.

Applicants have now discovered a method for making pigment-coated microbubbles which is efficient, inexpensive and causes minimal damage, even to thin-walled glass microbubbles.

Such method for making pigment-coated microbubbles comprises the steps of:

(a) placing into a hollow cylindrical container

- (1) uncoated microbubbles
- (2) an effective amount of pigment, and
- (3) at least two mixing rods, each of the rods having a length at least about equal to the interior diameter of the container, the rods having a combined surface area at least about 5% of the interior surface area of the container, and

(b) rolling the container for a period of from about 3 minutes to about 15 minutes.

Surprisingly, this simple procedure results in efficient distribution of the pigment onto the microbubbles, and adherence thereto with minimal damage to the microbubbles. The role of the mixing rods is critical to the efficiency of the process; when a similar method is used which omits the use of mixing rods, the resulting pigment-coated microbubbles are much less intense in color than pigment-coated microbubbles made via the method of the invention. Further, the substitution of mixing spheres or other common milling devices for the mixing rods results in a significant increase in breakage of the microbubbles.

The mixing rods preferably have a non-porous surface, and may be glass, ceramic or metal, e.g., aluminum, brass or stainless steel. The rods should have a length which is approximately equal to the interior diameter of the container, maximizing the surface contact of the rods with the microbubbles while minimizing any turbulent flow. Further, the rods should have a combined surface area of at least 5% of the interior surface area of the container, preferably at least about 7%, more preferably at least about 9% in order to more effectively distribute the pigment. The pigment is added to the uncoated microbubbles in a particulate form, rather than as a suspension or dispersion.

The rolling time should be at least about 3 minutes, and preferably about 5 minutes. However, the rolling time may vary dependent on such factors as the speed of the rolling, the quantity of bubbles, the color intensity desired, and the size of the container.

Pigment-coated microbubbles made by other methods which result in efficient distribution of the pigment onto the microbubbles and adherence thereto are also useful in tapes of the invention. Other methods include, but are not limited to, precoating the microbubbles with an organic binder in order to make the surface retain higher percentages of the pigment.

The acrylic pressure-sensitive adhesives useful in the present invention are alkyl acrylates, preferably monofunctional unsaturated acrylate esters of non-tertiary alkyl alcohols, the molecules of which have from 1 to about 14 carbon atoms. Included within this class of monomers are, for example, isooctyl acrylate, isononyl acrylate, 2-ethyl-hexyl acrylate, decyl acrylate, dodecyl acrylate, n-butyl acrylate, and hexyl acrylate. Preferred monomers include isooctyl acrylate, isononyl acrylate, and butyl acrylate. The alkyl acrylate monomers may be used to form homopolymers for the photopolymerizable polymer or they may be copolymerized with polar monomers. When copolymerized with strongly polar monomers, the alkyl acrylate monomer generally comprises at least about 75% of the photopolymerizable polymers. When copolymerized with moderately polar monomers, the alkyl acrylate monomer generally comprises at least about 70% of the photopolymerizable polymer.

The polar copolymerizable monomers may be selected from strongly polar monomers such as acrylic acid, itaconic acid, hydroxyalkyl acrylates, cyanoalkyl acrylates, acrylamides or substituted acrylamides, or from moderately polar monomers such as N-vinyl pyrrolidone, N-vinyl caprolactam, acrylonitrile, vinyl chloride or diallyl phthalate. The strongly polar copolymerizable monomer preferably comprises up to about 25%, more preferably up to about 15%. The moderately polar copolymerizable monomer preferably comprises up to about 50%, more preferably from 5% to about 30% of the photopolymerizable polymer.

Among pressure-sensitive adhesives which are useful for the pressure-sensitive adhesive layer of the novel tape are those which become tacky only at elevated temperatures, e.g., acrylic copolymers having average carbon-to-carbon chains of less than 4 carbon atoms or those comprising a polymer wherein methacrylic acid esters are substituted for portions of acrylic acid esters.

Where superior cohesive strengths are desired, the pressure-sensitive adhesive matrix of the novel tape should be crosslinked. Preferred crosslinking agents for an acrylic pressure-sensitive adhesive are multifunctional acrylates such as 1,6-hexanedioldiacrylate as well as those disclosed in U.S. Patent No. 4,379,201 (Heilman et al.), incorporated herein by reference. Crosslinking is especially easy to control when photopolymerizing the monomer in admixture with a multifunctional acrylate crosslinking agent. Other types of crosslinking agents are also useful, e.g., any of those taught in U.S. Patents 4,330,590 (Vesley), and 4,329,384 (Vesley et al.), both of which are incorporated by reference. Heat-activatable crosslinking agents such as a lower-alkoxylated amino formaldehyde condensate having C₁₋₄ alkyl groups, for example, hexamethoxymethyl melamine (available as Cyrnel™ 303 from American Cyanamid Co.) or tetramethoxymethyl urea (available as Beetle™ 65 from American Cyanamid Co.) or tetrabutoxymethyl urea (Beetle™

85) are also useful. Each of the crosslinking agents is useful in the range of from about 0.01% to about 1% of the total weight of the monomers.

Tapes of the invention may comprise more than one foamlike pressure-sensitive adhesive layer. In such tapes, the foamlike pressure-sensitive adhesive layers may comprise similar or dissimilar adhesives, in like or unlike thicknesses, having similar or different additives. At least one layer of the pressure-sensitive adhesive comprises pigment-coated microbubbles; additional layers may comprise additional pigment-coated microbubbles, coated with similar or differing pigments, or uncoated microbubbles.

Where a tape of the invention is to be adhered to a surface to which its pressure-sensitive adhesive layer would not form a strong bond, it may be desirable to apply to one or both faces of its pigment-coated microbubble-filled adhesive layer, a layer of microbubble-free pressure-sensitive adhesive which is specially selected for its adhesion to that surface.

Where photopolymerization is desirable, the pressure-sensitive adhesive matrix of the novel tape of the invention may also contain a photoinitiator to aid in polymerization of the monomers. Photoinitiators that are useful for polymerizing the acrylate monomer include the benzoin ethers, substituted benzoin ethers such as benzoin methyl ether or benzoin isopropyl ether, substituted acetophenones such as 2,2-diethoxyacetophenone, and 2,2-dimethoxy-2-phenylacetophenone, substituted alpha-ketols such as 2-methyl-2-hydroxypropiophenone, aromatic sulphonyl chlorides such as 2-naphthalene sulphonyl chloride, and photoactive oximes such as 1-phenyl-1,1-propanedione-2-(O-ethoxycarbonyl) oxime. Generally, the photoinitiator is present in an amount of from about 0.01 part to about 1.0 parts per 100 parts monomer weight (phr).

In situ polymerization can also be effected by thermal polymerization or by electron beam as taught in U.S. Patent No. 4,243,500 (Glennon), and U.S. Patent No. 2,956,904 (Hendricks), however, photopolymerization by ultraviolet radiation is generally preferred.

Other useful materials which can be blended into the pressure-sensitive adhesive include plasticizers, tackifiers, fibrous reinforcing agents, woven and nonwoven fabrics, foaming agents, fire retardants and viscosity adjusting agents.

An especially useful filler material is hydrophobic silica as disclosed in U.S. Patent No. 4,710,536 (Klingen, Zimmerman), incorporated herein by reference. In one preferred embodiment of the present invention, the pressure-sensitive adhesive layer further comprises from about 2 to about 15 phr of a hydrophobic silica having a surface area of at least 10 m²/g.

The coatable compositions used in tapes of the invention, especially the pressure-sensitive compositions, are preferably prepared by premixing together the photopolymerizable monomers and the polar copolymerizable monomer, if used, and photoinitiator. This premix is then partially polymerized to a viscosity in the range of from about 500 cps to about 5,000 cps to achieve a coatable syrup. Alternatively, the monomers may be mixed with a thixotropic agent such as fumed silica to achieve a coatable syrup composition.

Photopolymerization is preferably carried out in an inert atmosphere, such as nitrogen. An inert atmosphere may also be achieved by temporarily covering the photopolymerizable coating with a plastic film which is transparent to ultraviolet radiation, and irradiating through the film in air. If the photopolymerizable coating is not covered during photopolymerization, the permissible oxygen content of the inert atmosphere may be increased by mixing the coating with a combustible tin compound as taught in U.S. 4,303,485 (Levens), which also teaches such technique for making thick coatings in air.

The adhesive composition may be coated onto a backing or substrate prior to polymerization. This may be accomplished using any conventional means such as roller coating, dip coating or extrusion coating.

As used herein, the term "tape" includes but is not limited to, those adhesive strips which are single-coated adhesive layers permanently attached to a backing or support, double-coated adhesive strips having flexible supports with an adhesive layer on both sides thereof, and adhesive strips with no support or backing, such being typically releasably attached to a low-adhesion liner, and commonly called "transfer tapes".

The following tests may be used to evaluate tapes of the invention.

Static Shear Value at 70° C.

55

Two flat, rigid stainless steel plates are bonded together by a piece of an adhesive layer 1.27 cm x 2.5 cm square. Before testing, a 1000-g weight rests over the bonded area for 15 minutes. Then the bonded plates are placed in an air-circulating oven which has been preheated to 70° C, and after 15 minutes, a 500-

g weight is hung from one of the plates while the other plate is held in a position tilted 2° from the vertical to insure against any peel forces. The time at which the weight falls is the "Static Shear Value at 70° C". If no failure, the test is discontinued at 10,000 minutes. Only cohesive failures are reported.

5

T-Peel

T-peel is measured as in ASTM D-1876-72 except that the test tapes are 1.27 cm (0.5 inch) in width and are tested only two hours after being adhered to aluminum backings. Results are reported in Newtons per decimeter (N/dm). Only cohesive failures are reported.

10

180° Peel

15

The adhesive layer to be tested is transferred onto 0.05-mm thick, chemically primed, aluminum foil which then is slit to a width of 1.27 cm (1/2 inch). The resulting tape is self-adhered to a smooth stainless steel plate under the weight of a 2.04 kg hard-rubber-covered steel roller, 2 passes in each direction. After dwelling at 23° C for one hour, "180° Peel" is measured by moving the free end of the tape away from the steel plate at a rate of about 0.5 cm per second using a tensile tester.

20

90° Peel

25

The adhesive layer to be tested is transferred onto a 0.05-mm thick soft aluminum foil which then is slit to a width of 1.27 cm (1/2 inch). The resulting tape is self-adhered to a smooth stainless steel plate under the weight of a 5.5-kg hard-rubber-covered steel roller, one pass in each direction. After dwelling at 23° C for 20 minutes, the "90° Peel" is measured by moving the free end of the tape away from the steel plate at 90° and at a rate of about 0.5 cm per second using a tensile tester.

30

Darkness

35

The darkness of a pressure-sensitive adhesive layer is determined on a Hunter Labscan Spectrophotometer using a 10 degree reflectance, Illum = D85 and the CIE lab scale (L^* a^* b^*) where $L^* = 0$ is black and $L^* = 100$ is white. Since a^* and b^* for black samples are usually between -5 and +5, they are not reported unless one of them is outside of that range.

40

Pigments

45

Pigments used in making foamlike pressure-sensitive adhesive tapes of the invention include

50

55

Pigment	
Red	segnale red FGR
Blue	phthalocyanine blue
Yellow	chrome yellow
Black-1	"Raven" 1500 carbon black (Columbia Chemicals)
Black-2	"Raven" 1040 carbon black
Black-3	"Raven" H20 carbon black
Black-4	lampblack

Pigment-Coated Microbubbles A-H

These pigment-coated microbubbles are commercially available from Rose Labs. They were coated, it is believed, using an organic binder, onto glass microbubbles having an average density of 0.15 g/cm³ and 20-200 micrometers in diameter (average 55 micrometers) except that the glass microbubbles onto which the blue pigment was coated had an average density of 0.23g/cm³. Reported in Table I are calculations of the percentage of the pigment-coated microbubbles that comprise pigment.

Table I

Pigment coated Microbubbles	Pigment	% Pigment (by weight)	Average density ^{**} (g/cm ³)
A	Red	3.6	0.15
B	Blue	21	0.29
C	Yellow	51	0.27
D	Black-1	*	0.17
E	Black-1	*	0.16
F	Black-4	*	0.20
G	Black-1	*	0.15
H	Black-4	*	0.14

* It was found to be impossible to determine the % pigment of Pigment-coated Microbubbles D-H, but it is believed that the pigment loading of Pigment-Coated Microbubbles D was about five times that of each of Pigment-Coated Microbubbles E and F, and about 20 times that of each of Pigment-Coated Microbubbles G and H.

** Average density of pigment-coated microbubbles after removing a high-density fraction in order to eliminate any microbubbles that may have been broken and any malformed glass microbubbles.

Pigment-Coated Microbubbles I

Pigment-Coated Microbubbles I were coated by loading 8g of the above-described glass microbubbles and 0.4 g of pigment into a glass jar (1 quart; about 1 liter) which was closed and placed on a shaker for 5 minutes. The microbubbles took on the color of the pigment, and microscopic examination showed that each microbubble had become coated. The average density was unchanged. No further improvement in coating density or color intensity was observed with continued shaking for up to thirty minutes.

Pigment-Coated Microbubbles J-Q

Pigment-Coated Microbubbles J-Q were coated at varied pigment loadings in a glass jar as in the preceding paragraph, but the glass jar contained three aluminum rods, each 1.27 cm in diameter and 10 cm in length. Instead of using a shaker, the glass jar (after being wrapped with protective tape) was rolled at 120 rpm for 5 minutes. The microbubbles received a coating which was noticeably darker than the coating obtained by shaking. The density of the Pigment-Coated Microbubbles J-Q increased slightly as indicated in Table II, the increase being attributable to some breakage of microbubbles. When the rolling time was increased to 30 minutes, the density was about 0.3g/cm³, indicating substantial breakage, and the pigment-coated microbubbles had a deeper color, but these microbubbles were not used in testing.

Pigment-Coated Microbubbles R-S

Pigment-Coated Microbubbles R were made in the same way as Pigment-Coated Microbubbles I except using polymeric microbubbles ("Expancel" 551DE) having density of 0.036 g/cm³ and a diameter of 5-100 micrometers.

Pigment-Coated Microbubbles S were made in the same way as Pigment-Coated Microbubbles J-Q except using the polymeric microbubbles.

Table II

Pigment coated Microbubbles	Pigment	Ratio of pigment to glass (by weight)	Average density (g/cm ³)
I	Black-2	0.5	0.16
J	Black-2	0.5	0.19
K	Black-2	0.75	0.19
L	Black-2	1.0	0.18
M	Black-3	0.5	0.18
N	Black-1	0.5	0.19
O	Red	0.5	0.19
P	Blue	0.5	0.19
Q	Yellow	0.5	0.20
R	Black-2	0.19	0.037
S	Black-2	0.14	0.037

The following examples are for illustrative purposes only, and should not be construed as limiting the invention. All percents, parts and ratios listed are by weight unless otherwise specified.

Examples 1-13

To make each of the foamlike pressure-sensitive adhesive tapes of Examples 1-13, a syrup of coatable viscosity was prepared by partially polymerizing, as taught in U.S. Patent No. 4,330,590 (Vesley), a mixture of 87.5 parts Isooctyl acrylate, 12.5 parts acrylic acid, and 0.04 part of 2,2-dimethyl-2-phenyl acetophenone ("Irgacure" 651). An additional 0.1 part of "Irgacure" 651 was added to each aliquot of this syrup as well as 0.05 part of hexanedioldiacrylate, and 7 parts of pigment-coated glass microbubbles (1.8 parts when the microbubbles were polymeric). Each of the resulting mixtures was thoroughly mixed slowly with an air stirrer and carefully degassed in a dissector using a vacuum pump. The pigment-coated glass microbubbles comprised about 33% by volume of each mixture.

Each mixture was fed into the nip of a knife coater between a pair of transparent, biaxially-oriented poly(ethylene terephthalate) films, the facing surfaces of which had low-adhesion coatings. The knife coater was adjusted to provide a coating thickness of approximately 0.625mm for the tapes of Examples 1-4 and a thickness of approximately 1.0mm for Examples 5-13. The composite emerging from the knife coater was irradiated simultaneously from both sides with a bank of lamps, 90% of the emissions of which were between 300 and 400 nm with a maximum at 351 nm. Each side of the coating was exposed to a total radiation of 400-410 millijoules as measured by a Dynachem radiometer Model 500 which is spectrally responsive between 300 and 400 nm, maximum 350 nm. This total was corrected for the irradiation adsorbed by the poly(ethylene terephthalate) films. The composite was cooled by blowing air against both films during the irradiation to keep the temperature of the film below 85°C to avoid wrinkling of the films. Each of the foamlike pressure-sensitive adhesive tapes of Examples 1-13 had a density of about 720g/m³.

The tapes of Examples 1-13 incorporated pigment-coated microbubbles as reported in Tables III and IV. In some of the tapes of Table IV, a portion of the 7 parts of pigment-coated microbubbles had been replaced with the indicated parts of uncoated microbubbles.

Table III

Ex.	Pigment-coated Microbubbles	L*	a*	b*	T-peel (N/dm)	180° Peel (N/dm)
1	A	49	81	42	270	150
2	B	74	27	98	260	160
3	C	18	2	-25	210	140
4	G	27			300	150
Control™		93			300	150

™ Control tape made using uncoated glass microbubbles.

Table IV

Ex.	Pigment-coated Microbubbles	Uncoated Microbubbles (parts)	L*	a*	b*	T-peel (N/dm)	180° Peel (N/dm)
5	A		45	81	38	310	150
6	B		19	-2	-23	290	150
7	C		33	93	40	310	110
8	D		16			300	200
9	D	3.5	29			340	170
10	E	1.8	17			350	110
11	E	2.1	22			330	130
12	F		15			310	120
13	H	1.4	28			320	140

Comparative Examples C1-C6

Tapes of Comparative Examples C1-C6 were made in the same way as the tapes of Examples 5-13, except that these tapes did not incorporate pigment-coated microbubbles; rather, the tapes incorporate a like volume of uncoated microbubbles. For each tape, the listed amount of pigment was added directly to each aliquot of syrup as a dispersion in phenoxyethyl acrylate (Penn Color). Each of the foamlike pressure-sensitive adhesive tapes of Comparative Examples C1-C6 had a density of about 720g/m³.

Table V

Ex.	Pigment (phr)	L*	T-peel (N/dm)	180° Peel (N/dm)
C1	0.034	48	350	149
C2	0.06	38	324	182
C3	0.07	38	324	158
C4	0.08	31	280	173
C5	0.10	28	252	182
C6	0.12	28	219	142
Control™	0	94	372	153

™Control made without addition of pigment

As can be seen from the above data, tapes having pigment added directly to the syrup exhibit a reduction in adhesive properties as the amount of pigment is increased. This is due to reduced transmission

of the ultraviolet radiation resulting from the darker color. Tapes of the invention do not exhibit a like reduction in properties at comparative darknesses (L^* values). See, e.g., Examples 8-13.

Examples 14-24

Tapes of Examples 14-24 were made in the same way as the tapes of Examples 5-13, except that 2.0 parts of Degussa Aerosil™ 972 were added. Test results are reported in Table VI. Each of the tapes of Examples 14-22 had a density of about 800-830 kg/m³, and those of Examples 23-24 had a density of about 700 kg/m³.

Table VI

Ex.	Pigment-coated Microbubbles	L^*	a^*	b^*	T-peel (N/dm)	90° Peel (N/dm)
14	I	55			370	310
15	J	38			370	270
16	K	31			350	300
17	L	29			340	320
18	M	52			360	340
19	N	63			380	230
20	O	86	-3	40	380	270
21	P	64	-27	-30	370	230
22	Q	90	-1	19	410	240
23	R	61			270	340
24	S	45				

Each of the foamlike pressure-sensitive adhesive tapes of Examples 1-23 had a Static Shear Value at 70° C of greater than 10,000 minutes.

Claims

1. A foamlike pressure-sensitive adhesive tape comprising a flexible carrier supporting one or more pressure-sensitive adhesive layers, at least one layer of said pressure-sensitive adhesive having pigment-coated microbubbles dispersed therein, said microbubbles having an average diameter from 5 to 200 micrometers, wherein said pigment coat comprises finely divided pigment particles, the average particle size being no greater than 1/100 the average size of said microbubbles.

2. Pressure-sensitive adhesive tape as defined in claim 1 wherein said pigment-coated microbubbles selected from glass and polymeric microbubbles.

3. Pressure-sensitive adhesive tape as defined in claim 1 wherein said pigment-coated microbubbles comprise from about 5% to about 65% by weight of said pressure-sensitive adhesive layer.

4. Pressure-sensitive adhesive tape as defined in claim 1 wherein said pressure-sensitive adhesive layers comprise at least one copolymer of monomers comprising (a) acrylic acid ester of nontertiary alcohol, the molecules of which contain from 1 to about 14 carbon atoms, and (b) a polar copolymerizable monomer.

5. A pressure-sensitive adhesive tape according to any of claims 1-4 wherein said pressure-sensitive adhesive comprises

(a) from about 85 parts to about 99 parts of isooctyl acrylate, and correspondingly, from about 1 to about 15 parts of a strongly polar copolymerizable monomer selected from the group consisting of acrylic acid, methacrylic acid, itaconic acid, acrylamide and methacrylamide, and

(b) from about 0.01 part to about 1.0 part of a crosslinking agent selected from the group consisting of hexanedioldiacrylate, a lower-alkoxylated amino formaldehyde condensate, and 2,4-bis(trichloromethyl)-6-methoxyphenyl-s-triazine.

6. A pressure-sensitive adhesive tape according to any of claims 1-4 wherein said pressure-sensitive adhesive comprises

(a) a polymer of 70-100 parts of substituted or unsubstituted acrylate monomer and correspondingly 30-0 parts of a moderately polar copolymerizable monomer selected from the group consisting of N-vinylpyrrolidone, N-vinylcaprolactam, vinyl chloride and acrylonitrile, and

(b) from about 0.01 part to about 1 part of a crosslinking agent selected from the group consisting of hexanedioldiacrylate, a lower-alkoxylated amino formaldehyde condensate, and 2,4-bis(trichloromethyl)-6-methoxyphenyl-s-triazine.

7. A method of making pigment-coated microbubbles comprising the steps of:

(a) placing into a hollow cylindrical container

(1) uncoated microbubbles

(2) an effective amount of pigment, and

(3) at least two mixing rods, each of said rods having a length at least about equal to the interior diameter of said container, said rods having a combined surface area at least about 5% of the interior surface area of said container, and

(b) rolling the container for a period of from about 3 minutes to about 15 minutes.

8. A method of making pigment-colored microbubbles according to claim 7 wherein at least 3 mixing rods are placed into said hollow cylindrical container, said mixing rods having a combined surface area at least about 9% of the interior surface area of said container.

9. Pigment-coated microbubbles made by the method of claim 7 or 8.

10. A colored pressure-sensitive adhesive tape comprising an acrylate adhesive containing pigment-colored microbubbles made by the method of claim 7 or 8.